

What is claimed is:

1. A radio-wave arrival-direction estimating apparatus comprising:
  - an array antenna including a plurality of antenna elements;
  - a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;
  - an A/D converter for converting the demodulated signal to a complex digital signal;
  - a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;
  - a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;
  - a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;
- 20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and
- 25 an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

2. A radio-wave arrival-direction estimating apparatus according to claim

1 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

5 said noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

3. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes input matrix R to  
10 product  $U^H U$  of upper triangular matrix U by cholesky factorization.

4. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes input matrix R to product  $LL^H$  of lower triangular matrix L by cholesky factorization.

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5. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes an input matrix to product  $U^H D U$  of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

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6. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes an input matrix to product  $LDL^H$  of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

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7. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said correlation matrix calculation unit calculates a correlation matrix,

applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

8. A radio-wave arrival-direction estimating apparatus according to claim  
5 1, wherein

    said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

    said arrival-angle evaluation unit comprises

    a positive-region evaluation unit for calculating an evaluation value  
10 of an arrival-angle evaluation function for positive angle  $\theta$  with reference to a bore-sight direction of said array antenna, and

    a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle ( $-\theta$ ).

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9. A radio-wave arrival-direction estimating apparatus according to claim  
1, wherein

    said array antenna has a linear array shape, and

    said arrival-angle evaluation unit sets an angle interval in an end fire  
20 direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

10. A radio-wave arrival-direction estimating apparatus according to  
25 claim 1, further comprising:

    a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval

smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately  
5 determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

11. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;  
10 an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;  
an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;  
15 a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;  
a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;  
20 a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;  
a triangular matrix calculation unit for factorizing a matrix including a  
25 product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

5           an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

12. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

10          a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

              an A/D converter for converting the demodulated signal to a complex digital signal;

15          a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

              an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

20          a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

              an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

25           an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

13. A radio-wave arrival-direction estimating apparatus according to claim 12 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

5           the plurality of antenna elements are arranged linearly at a constant interval, and

              said inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

10           14. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes input matrix R to product  $U^H U$  of upper triangular matrix U by cholesky factorization.

15           15. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes input matrix R to product  $LL^H$  of lower triangular matrix L by cholesky factorization.

20           16. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes an input matrix to product  $U^H D U$  of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

25           17. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes an input matrix to product  $LDL^H$  of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

18. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

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19. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein

    said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

10       said arrival-angle evaluation unit comprises

        a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle  $\theta$  with reference to a bore-sight direction of said array antenna, and

15       a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle  $(-\theta)$ .

20. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein

20       said array antenna has a linear array shape, and

        said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

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21. A radio-wave arrival-direction estimating apparatus according to claim 12, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

10            22. A radio-wave arrival-direction estimating apparatus comprising:

- an array antenna including a plurality of antenna elements;
- an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;
- 15            an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;
- a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;
- a correlation matrix calculation unit for calculating a correlation matrix
- 20            by correlation calculation of the complex digital signal between the antenna elements;
- an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;
- a triangular matrix calculation unit for factorizing the inverse matrix to
- 25            a product of one of an upper triangular matrix and a lower triangular matrix;
- an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle

evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

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23. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a ...RF... signal received by each of the antenna elements in said array antenna, demodulating 10 the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna 15 elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of the upper triangular matrix and the lower triangular matrix;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

25 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

24. A radio-wave arrival-direction estimating apparatus according to

claim 23 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

5        said triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix.

25. A radio-wave arrival-direction estimating apparatus according to  
10      claim 23, wherein said triangular matrix calculation unit factorizes input matrix R to product  $U^H U$  of upper triangular matrix U by cholesky factorization.

26. A radio-wave arrival-direction estimating apparatus according to  
claim 23, wherein said triangular matrix calculation unit factorizes input matrix  
15      R to product  $LL^H$  of lower triangular matrix L by cholesky factorization.

27. A radio-wave arrival-direction estimating apparatus according to  
claim 23, wherein said triangular matrix calculation unit factorizes an input  
matrix to product  $U^H D U$  of upper triangular matrix U and diagonal matrix D by  
20      modified cholesky factorization.

28. A radio-wave arrival-direction estimating apparatus according to  
claim 23, wherein said triangular matrix calculation unit factorizes an input  
matrix to product  $LDL^H$  of lower triangular matrix L and diagonal matrix D by  
25      modified cholesky factorization.

29. A radio-wave arrival-direction estimating apparatus according to

claim 23, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

5           30. A radio-wave arrival-direction estimating apparatus according to claim 23, wherein

               said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

               said arrival-angle evaluation unit comprises

10           a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle  $\theta$  with reference to a bore-sight direction of said array antenna, and

               a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value  
15           for negative angle  $(-\theta)$ .

31. A radio-wave arrival-direction estimating apparatus according to claim 23, wherein

               said array antenna has a linear array shape, and

20           said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

25           32. A radio-wave arrival-direction estimating apparatus according to claim 23, further comprising:

               a high-accuracy arrival-angle evaluation unit for calculating an

evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

5           a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

33. A radio-wave arrival-direction estimating apparatus comprising:

10           an array antenna including a plurality of antenna elements;

              an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

15           an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

              a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

              a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna

20           elements;

              a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

              an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

25           an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the

upper triangular matrix and the lower triangular matrix; and  
an arrival-angle determination unit for determining an arrival angle  
based on the evaluation value by said arrival-angle evaluation unit.

5           34. A radio-wave arrival-direction estimating apparatus comprising:  
an array antenna including a plurality of antenna elements;  
a receiving unit for converting frequency of a RF signal  
received by each of the antenna elements in said array antenna, demodulating  
the converted signal, and outputting the demodulated signal;

10          an A/D converter for converting the demodulated signal to a complex  
digital signal;  
a correlation matrix calculation unit for calculating a correlation matrix  
by correlation calculation of the complex digital signal between the antenna  
elements;

15          a triangular matrix calculation unit for factorizing the correlation matrix  
to a product of one of an upper triangular matrix and a lower triangular matrix;  
an arrival-angle evaluation unit for calculating an evaluation value of an  
arrival-angle evaluation function every predetermined angle, the arrival-angle  
evaluation function being expressed using the one of the upper triangular matrix  
20         and the lower triangular matrix; and  
an arrival-angle determination unit for determining an arrival angle  
based on the evaluation value by said arrival-angle evaluation unit.

35. A radio-wave arrival-direction estimating apparatus according to  
25 claim 34 further comprising a unitary transforming unit for unitary-transforming  
the correlation matrix, wherein  
the plurality of antenna elements are arranged linearly at a constant

interval, and

    said triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix.

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36. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes input matrix R to product  $U^H U$  of upper triangular matrix U by cholesky factorization.

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37. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes input matrix R to product  $LL^H$  of lower triangular matrix L by cholesky factorization.

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38. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes an input matrix to product  $U^H D U$  of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

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39. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes an input matrix to product  $LDL^H$  of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

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40. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

41. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein

5        said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

      said arrival-angle evaluation unit comprises

          a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle  $\theta$  with reference to a bore-sight direction of said array antenna, and

10        a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle (- $\theta$ ).

42. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein

      said array antenna has a linear array shape, and

      said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

43. A radio-wave arrival-direction estimating apparatus according to claim 34, further comprising:

25        a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-

angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

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44. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

15 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

25 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

45. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

5 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected 10 complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle 15 based on the evaluation value by said arrival-angle evaluation unit.

46. A radio-wave arrival-direction estimating apparatus according to claim 45 further comprising a unitary transforming unit for unitary-transforming the correlation vector, wherein

20 the plurality of antenna elements are arranged linearly at a constant interval, and

said arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation 25 vector.

47. A radio-wave arrival-direction estimating apparatus according to

claim 45, wherein

    said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

    said arrival-angle evaluation unit comprises

5           a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle  $\theta$  with reference to a bore-sight direction of said array antenna, and

10          a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle ( $-\theta$ ).

48. A radio-wave arrival-direction estimating apparatus according to claim 45, wherein

    said array antenna has a linear array shape, and

15          said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

20          49. A radio-wave arrival-direction estimating apparatus according to claim 45, further comprising:

    a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in  
25          a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

    a high-accuracy arrival-angle determination unit for highly accurately

determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

50. A radio-wave arrival-direction estimating apparatus comprising:

- 5       an array antenna including a plurality of antenna elements;
- an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;
- 10      an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;
- a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;
- 15      a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;
- an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and
- 20      an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

51. A directivity variable receiver comprising:

- a radio-wave arrival-direction estimating apparatus including:
  - 25      an array antenna having a plurality of antenna elements;
  - a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the

converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit;

a plurality of sector antennas having different main beam directions;

a sector control unit for outputting a sector control signal used for selecting one sector antenna from said plurality of sector antennas, the selected sector antenna having a beam direction in a direction estimated by said radio-wave arrival-direction estimating apparatus;

a sector switch for alternatively coupling the sector antenna based on the sector control signal; and

20 a receiving unit for demodulating an output signal of said sector switch.

52. A directivity variable receiver according to claim 51, wherein the plurality of antenna elements are arranged linearly at a constant interval,

25 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and

the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

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53. A directivity variable receiver according to claim 51,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

10 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

15 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a 20 row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix 25 and a lower triangular matrix; and

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle

evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

54. A directivity variable receiver according to claim 53, wherein  
the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

10 the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

55. A directivity variable receiver according to claim 51,  
wherein said radio-wave arrival-direction estimating apparatus  
15 comprises:

an array antenna including a plurality of antenna elements;  
a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

20 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

25 an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

a triangular matrix calculation unit for factorizing the inverse matrix

to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

56. A directivity variable receiver according to claim 55, wherein

10 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

15 the inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

57. A directivity variable receiver according to claim 51,

wherein said radio-wave arrival-direction estimating apparatus  
20 comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

25 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation

matrix by correlation calculation of the complex digital signal between the antenna elements;

5        a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

10      an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

15      58. A directivity variable receiver according to claim 57, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

20      said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

25      59. A directivity variable receiver according to claim 51,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

5 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

10 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

15 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

20 60. A directivity variable receiver according to claim 59, wherein  
the plurality of antenna elements are arranged linearly at a constant interval,  
said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and  
25 the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower

triangular matrix

61. A directivity variable receiver comprising:
  - a radio-wave arrival-direction estimating apparatus including:
    - 5 an array antenna having a plurality of antenna elements;
    - a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;
    - 10 an A/D converter for converting the demodulated signal to a complex digital signal;
    - a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;
  - 15 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit;
  - 20 a directivity control unit for assigning a complex weight to the demodulated signal and combines the signals with each other so as to generate directivity of the array antenna to an arrival direction of the radio-wave arrival-direction estimating apparatus; and a receiving unit for demodulating an output signal of the directivity control unit.
62. A directivity variable receiver according to claim 61, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and

the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

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63. A directivity variable receiver according to claim 61,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

15 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

20 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a 25 row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

a triangular matrix calculation unit for factorizing a matrix including a

product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

an arrival-angle evaluation unit for calculating an evaluation value of  
5 an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

64. A directivity variable receiver according to claim 63, wherein  
10 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

15 the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

65. A directivity variable receiver according to claim 61,  
wherein said radio-wave arrival-direction estimating apparatus  
20 comprises:

an array antenna including a plurality of antenna elements;  
a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;  
25 an A/D converter for converting the demodulated signal to a complex digital signal;  
a correlation matrix calculation unit for calculating a correlation

matrix by correlation calculation of the complex digital signal between the antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

5           a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

10           an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

66. A directivity variable receiver according to claim 65, wherein

15           the plurality of antenna elements are arranged linearly at a constant interval,

              said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

20           the inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

67. A directivity variable receiver according to claim 61,

              wherein said radio-wave arrival-direction estimating apparatus  
25           comprises:

              an array antenna including a plurality of antenna elements;

              a receiving unit for converting frequency of a RF signal

received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

5        a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular

10      matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-

15      angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

20      68. A directivity variable receiver according to claim 67, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation

25      matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower

triangular matrix

69. A directivity variable receiver according to claim 61,

wherein said radio-wave arrival-direction estimating apparatus

5 comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

10 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

15 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

25 70. A directivity variable receiver according to claim 69, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

71. A directivity variable transmitter comprising:

- a radio-wave arrival-direction estimating apparatus including:
  - 10 an array antenna having a plurality of antenna elements;
  - a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;
  - 15 an A/D converter for converting the demodulated signal to a complex digital signal;
  - a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;
  - 20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and
  - an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit;
  - 25 a plurality of sector antennas having different main beam directions;
  - a sector control unit for outputting a sector control signal used for selecting one sector antenna from said plurality of sector antennas, the selected

sector antenna having a beam direction in a direction estimated by said radio-wave arrival-direction estimating apparatus;

a sector switch for alternatively coupling the sector antenna based on the sector control signal; and

5           a transmitting unit for transmitting a modulated signal after frequency conversion from said sector antennas.

72. A directivity variable transmitter according to claim 71, wherein

the plurality of antenna elements are arranged linearly at a constant  
10 interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and

the arrival-angle evaluation unit calculates an evaluation value of an  
15 arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

73. A directivity variable transmitter according to claim 71,

20           wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

25           a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

5 a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

10 a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

15 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

74. A directivity variable transmitter according to claim 73, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

20 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

25

75. A directivity variable transmitter according to claim 71,

wherein said radio-wave arrival-direction estimating apparatus

comprises:

- an array antenna including a plurality of antenna elements;
- 5 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;
- an A/D converter for converting the demodulated signal to a complex digital signal;
- 10 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;
- an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;
- 15 a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;
- an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and
- 20 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

- 76. A directivity variable transmitter according to claim 75, wherein
  - the plurality of antenna elements are arranged linearly at a constant interval,
  - 25 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

77. A directivity variable transmitter according to claim 71,

5           wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

10           a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

15           a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

20           an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

25           an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

78. A directivity variable transmitter according to claim 77, wherein  
the plurality of antenna elements are arranged linearly at a constant  
interval,

5 said radio-wave arrival-direction estimating apparatus further  
comprises a unitary transforming unit for unitary-transforming the correlation  
matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed  
correlation matrix to a product of one of an upper triangular matrix and a lower  
triangular matrix

10

79. A directivity variable transmitter according to claim 71,  
wherein said radio-wave arrival-direction estimating apparatus  
comprises:

an array antenna including a plurality of antenna elements;  
15 a receiving unit for converting frequency of a RF signal  
received by each of the antenna elements in the array antenna, demodulating the  
converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex  
digital signal;

20 a correlation matrix calculation unit for calculating a correlation  
matrix by correlation calculation of the complex digital signal between the  
antenna elements;

a triangular matrix calculation unit for factorizing the correlation  
matrix to a product of one of an upper triangular matrix and a lower triangular  
25 matrix;

an arrival-angle evaluation unit for calculating an evaluation value of  
an arrival-angle evaluation function every predetermined angle, the arrival-

angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

5

80. A directivity variable transmitter according to claim 79, wherein the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further 10 comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

15

81. A directivity variable transmitter comprising:

a radio-wave arrival-direction estimating apparatus including:

an array antenna having a plurality of antenna elements;

20 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

25 a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle

5 based on the evaluation value by the arrival-angle evaluation unit;

a transmitting unit for generating a transmitted signal;

a directivity control unit for assigning a complex weight to the transmitted signal so as to generate antenna directivity to an arrival direction determined by the radio-wave arrival-direction estimating apparatus;

10 a transmitting unit for converting frequency of an output from said directivity control unit; and

an array antenna for transmitting an output from said transmitting unit.

82. A directivity variable transmitter according to claim 81, wherein

15 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and

20 the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

25 83. A directivity variable transmitter according to claim 81,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

5 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

10 a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

15 a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

84. A directivity variable transmitter according to claim 83, wherein  
 the plurality of antenna elements are arranged linearly at a constant  
 25 interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation

matrix, and

the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

- 5        85. A directivity variable transmitter according to claim 81,  
          wherein said radio-wave arrival-direction estimating apparatus  
          comprises:
  - an array antenna including a plurality of antenna elements;
  - 10      a receiving unit for converting frequency of a RF signal  
          received by each of the antenna elements in the array antenna, demodulating the  
          converted signal, and outputting the demodulated signal;
  - 15      an A/D converter for converting the demodulated signal to a complex  
          digital signal;
  - 20      a correlation matrix calculation unit for calculating a correlation  
          matrix by correlation calculation of the complex digital signal between the  
          antenna elements;
  - 25      an inverse matrix calculation unit for calculating an inverse matrix of  
          the correlation matrix;
  - a triangular matrix calculation unit for factorizing the inverse matrix  
          to a product of one of an upper triangular matrix and a lower triangular matrix;
  - an arrival-angle evaluation unit for calculating an evaluation value of  
          an arrival-angle evaluation function every predetermined angle, the arrival-  
          angle evaluation function being expressed using the one of the upper triangular  
          matrix and the lower triangular matrix; and
  - 25      an arrival-angle determination unit for determining an arrival angle  
          based on the evaluation value by the arrival-angle evaluation unit.

86. A directivity variable transmitter according to claim 85, wherein  
the plurality of antenna elements are arranged linearly at a constant  
interval,

said radio-wave arrival-direction estimating apparatus further  
5 comprises a unitary transforming unit for unitary-transforming the correlation  
matrix, and

the inverse matrix calculation unit calculates an inverse matrix of the  
unitary-transformed correlation matrix.

10 87. A directivity variable transmitter according to claim 81,  
wherein said radio-wave arrival-direction estimating apparatus  
comprises:

an array antenna including a plurality of antenna elements;  
a receiving unit for converting frequency of a RF signal  
15 received by each of the antenna elements in the array antenna, demodulating the  
converted signal, and outputting the demodulated signal;  
an A/D converter for converting the demodulated signal to a complex  
digital signal;

20 a correlation matrix calculation unit for calculating a correlation  
matrix by correlation calculation of the complex digital signal between the  
antenna elements;

a triangular matrix calculation unit for factorizing the correlation  
matrix to a product of one of an upper triangular matrix and a lower triangular  
matrix;

25 an inverse matrix calculation unit for calculating an inverse matrix of  
the one of the upper triangular matrix and the lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of

an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle  
5 based on the evaluation value by the arrival-angle evaluation unit.

88. A directivity variable transmitter according to claim 87, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

10 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower 15 triangular matrix

89. A directivity variable transmitter according to claim 81,

wherein said radio-wave arrival-direction estimating apparatus comprises:

20 an array antenna including a plurality of antenna elements;  
a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex 25 digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the

antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

5           an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

10           an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

90. A directivity variable transmitter according to claim 89, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

15           said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

20           the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

91. A directivity variable transceiver comprising:

a radio-wave arrival-direction estimating apparatus including:

an array antenna having a plurality of antenna elements;

25           a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

5           a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

10           an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit;

a plurality of sector antennas having different main beam directions;

15           a sector control unit for outputting a sector control signal used for selecting one sector antenna from said plurality of sector antennas, the selected sector antenna having a beam direction in a direction estimated by said radio-wave arrival-direction estimating apparatus;

a sector switch for alternatively coupling the sector antenna based on the sector control signal;

a receiving unit for performing demodulation;

20           a transmitting unit for performing transmission; and

a switch coupled to the sector antenna for feeding an signal supplied from the selected sector antenna into said receiving unit or for outputting a transmitted signal from said transmitting unit through the selected sector antenna.

25

92. A directivity variable transceiver according to claim 91, wherein

the plurality of antenna elements are arranged linearly at a constant

interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and

5           the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

10           93. A directivity variable transceiver according to claim 91,

              wherein said radio-wave arrival-direction estimating apparatus comprises:

              an array antenna including a plurality of antenna elements;

              a receiving unit for converting frequency of a RF signal

15          received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

              an A/D converter for converting the demodulated signal to a complex digital signal;

20          a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

              a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging

25          to a noise eigen-space;

              a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix

of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

94. A directivity variable transceiver according to claim 93, wherein  
the plurality of antenna elements are arranged linearly at a constant  
10 interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

95. A directivity variable transceiver according to claim 91,  
wherein said radio-wave arrival-direction estimating apparatus  
comprises:

20 an array antenna including a plurality of antenna elements;  
a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

25 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the

antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

5        a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

10        an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

96. A directivity variable transceiver according to claim 95, wherein

the plurality of antenna elements are arranged linearly at a constant  
15        interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the inverse matrix calculation unit calculates an inverse matrix of the  
20        unitary-transformed correlation matrix.

97. A directivity variable transceiver according to claim 91,

wherein said radio-wave arrival-direction estimating apparatus comprises:

25        an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the

converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

5 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

10 an inverse matrix calculation unit for calculating an inverse matrix of the one of the upper triangular matrix and the lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

15 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

98. A directivity variable transceiver according to claim 97, wherein

20 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

25 the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

99. A directivity variable transceiver according to claim 91,

wherein said radio-wave arrival-direction estimating apparatus comprises:

5           an array antenna including a plurality of antenna elements;

              a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

10          an A/D converter for converting the demodulated signal to a complex digital signal;

              a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

15          a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

              an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

20          an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

100. A directivity variable transceiver according to claim 99, wherein

25          the plurality of antenna elements are arranged linearly at a constant interval,

              said radio-wave arrival-direction estimating apparatus further

comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

5

101. A radio-wave arrival-direction estimating method comprising:

(a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation  
10 between the antenna elements;

(b) calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

(c) factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;

15 (d) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and  
20

(e) determining an arrival angle based on the evaluation value every predetermined angle.

25 102. A radio-wave arrival-direction estimating method according to claim 101 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are

arranged linearly at a constant interval.

103. A radio-wave arrival-direction estimating method comprising:

- (a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation between the antenna elements;
- (b) calculating an inverse matrix of the correlation matrix;
- (c) factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;
- 10 (d) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and
- 15 (e) determining an arrival angle based on the evaluation value every predetermined angle.

104. A radio-wave arrival-direction estimating method according to claim 103 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are 20 arranged linearly at a constant interval.

105. A radio-wave arrival-direction estimating method comprising:

- (a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation 25 between the antenna elements;
- (b) factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

- (c) calculating an inverse matrix of the one of the upper triangular matrix and the lower triangular matrix;
- (d) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and
- (e) determining an arrival angle based on the evaluation value every predetermined angle.

10        106. A radio-wave arrival-direction estimating method according to claim 105 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are arranged linearly at a constant interval.

15        107. A radio-wave arrival-direction estimating method comprising:

- (a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation between the antenna elements;
- (b) factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;
- (c) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and
- (e) determining an arrival angle based on the evaluation value every predetermined angle.

20

25

108. A radio-wave arrival-direction estimating method according to claim 107 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are arranged linearly at a constant interval.

5

109. A radio-wave arrival-direction estimating method comprising:

(a) calculating a correlation vector of signals received by an array antenna including a plurality of the antenna elements by correlation calculation between a reference antenna element and another antenna element;

10 (b) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

(c) determining an arrival angle based on the evaluation value every predetermined angle.

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110. A radio-wave arrival-direction estimating method according to claim 109 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are arranged linearly at a constant interval.

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